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Original

Applications of Spectral Methods in Computational Electromagnetics / Tibaldi, Alberto; Orta, Renato. - ELETTRONICO. - (2016). (Intervento presentato al convegno Recent trends in the analysis of spectral problems and applications tenutosi a Torino nel 15 - 16 Settembre 2016).

Availability:

This version is available at: 11583/2652821 since: 2016-10-12T10:16:01Z

Publisher:

Politecnico di Torino

Published

DOI:

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Applications of Spectral Methods in Computational Electromagnetics

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The majority of the numerical methods developed in the computational electromagnetics context fall into one of the following categories: the ones solving integral equations, such as the method of moments, and those working on partial differential equations (PDEs), *e.g.* finite-difference (FD) or finite-element methods (FEM). Focusing on the latter class, we will describe an application of spectral methods.

Even if spectral methods have been introduced in the mid-1940s, their first rigorous study was carried out by Gottlieb and Orszag in 1977, who summarized the state of the art in their theory and application. Then, domain decomposition approaches were introduced to extend spectral methods to complex domains, generating a class of schemes known as spectral element methods (SEMs). Among all the schemes that have been developed, the mortar element method (MEM) is very interesting: here, local basis functions are defined in each sub-domain; then, they are “glued” at the common edges of adjacent patches by enforcing continuity conditions almost everywhere. This allows to use different resolutions in different patches (*i.e.* different degrees of the basis functions), and the possibility to hybridize this numerical method, joining it with other schemes.

A formulation of scattering problems concerning electromagnetic passive structures will be described. This is based on the decomposition of the structure into two sub-regions, an internal and an external one, by applying the equivalence theorem. Electric and magnetic current densities are used to provide the excitation of the internal boundary-value problem, which consists of a system of coupled PDEs obtained from Maxwell’s equations. Then, the numerical procedure aimed at synthesizing the expansion and test functions is described. Finally, this formulation is applied to two classes of 2-D electromagnetic devices: dielectric periodic structures (diffraction gratings) and axisymmetric waveguide components. The domain decomposition strategy for dielectric structures is conveniently chosen in such a way to obtain domains with homogeneous dielectric, preventing Gibbs phenomena and then ensuring fast convergence rates. Moreover, the flexibility in the geometry description opens up the possibility to describe well structures with rounded dielectric corners without any profile discretization. On the other hand, metallic waveguide components exhibiting sharp metal corners can be effectively studied by augmenting the MEM basis functions including the asymptotic field behavior, reducing in this way the number of functions required for an adequate field representation.